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Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fibre posts

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Abstract

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Aim To evaluate the mechanical behaviour of structurally compromised root filled bovine roots after restoration with accessory glass fibre posts.

Methodology Fifty roots of bovine teeth received conventional post preparations with a cervical diameter of 3.5 mm. The roots were assigned to five groups ($n = 10$): group MP – cast metal post, group GP – glass fibre post and group AGP – glass fibre post plus accessory glass fibre posts. In groups GP-R and AGP-R (similar to groups GP and AGP), 2 mm of coronal tooth structure were left intact. All groups were subjected to an elastic limit assay and tested in an universal machine for fracture resistance. Repeated measures ANOVA were performed to examine differences in fracture resistance; fracture modes were analysed by Fischer's exact test.

Results The mean fracture resistance values (kgf) were 61.8 (MP), 63.1 (GP), 55.5 (AGP), 56 (GP-R) and (53.1) AGP-R. No statistically significant difference was found between groups. The Fisher's exact test indicated significant differences ($P < 0.05$) in the fracture mode amongst groups MP, GP and AGP, indicating 100%, 50% and 10% of catastrophic fractures, respectivelly.

Conclusions The use of accessory glass fibre posts affected the fracture mode favorably: 90% of fractures in group AGP were in the coronal third.

Keywords: cast metal post, fracture resistance, glass fibre post, pre-fabricated post, root fracture.

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Introduction

The restoration of root filled teeth is a challenge. Loss of tooth structure although carious lesions, fractures and as a result of root canal treatment leads to weakening of the remaining tooth tissues (Gutmann 1992). When the coronal restoration is associated with an intraradicular post, the likelihood of restoration failure increases, with root fracture one of the most unfavourable outcomes (Qualtrough & Mannocci 2003).

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To prevent fractures, factors such as the amount of remaining tooth structure, the mechanical resistance of the post and bonding between the canal walls and restoration must be considered (Sornkul & Stannard 1992). Although a cast metal post and core is the traditional approach because of its proven clinical effectiveness (Solomon & Osman 2003), its mechanical properties may increase the risk of root fracture (Hornbrook & Hastings 1995).

As an alternative to metal, pre-fabricated posts made of glass fibres in a matrix of epoxy resin were developed (Duret *et al.* 1990). They have high mechanical resistance and their modulus of elasticity is similar to that of dentine (Fokkinga *et al.* 2004). Such properties would allow them to form a homogeneous complex with the root and provide absorption of loads comparable with a sound tooth (Duret *et al.* 1990). In

addition, because of their translucency, glass fibre posts contribute to the aesthetic qualities of tooth-coloured restorations (Ferrari *et al.* 2001).

Nonetheless, in cases of excessively wide root canal preparations, the extra space for the cement would impair the resistance to fracture of the roots (Kimmel 2000, Marchi *et al.* 2003).

The purpose of this study was to investigate the fracture resistance of root filled teeth, considering an innovative technique (accessory glass fibre posts) for wide root canals as well as the influence of the amount of remaining sound tooth structure in the coronal third. Resistance values were obtained by a tangential compression test. The mechanical behaviour of the treated roots was evaluated through analysis of their fracture modes.

Materials and methods

One hundred and fifty bovine incisors were extracted and stored in a 0.5% T-chloramine solution until cleaning. After that, the coronal portion of each tooth was sectioned 17 mm coronal to the root apex using a diamond double-face disk (KGSorensen, Sao Paulo, SP, Brazil) cooled with water. Fifty of the teeth were then selected statistically on the basis of their root canal diameter. The buccolingual and mesiodistal diameters for each tooth were obtained using a digital caliper (Z & Y Co., Qindao, Shandong, China) and the average was calculated for each root. Descriptive statistics was used to analyse the samples, based on the collection of the averages. According to the results (root average diameter of 6.90 mm with coefficient of variation 2.15%), the roots were similar in size. Following the selection process, the roots were stored in a 0.9% saline solution.

Thirty teeth were adjusted to a length of 15 mm, whilst 20 remained 17 mm long. Root canals were prepared with number 4138 diamond bur (KG Sorensen) in a high-speed water-cooled handpiece and a size 5 Largo drill (Dentsply Maillefer, Ballaigues, Switzerland). Depths of preparations were 10 mm for the 15 mm roots and 12 mm for the 17 mm roots.

To simulate weakened roots, a diameter of 3.5 mm was established at the entrance of all canals during preparation, whilst convergent walls were created towards the apical third, reproducing the external root morphology, with the same remaining wall thickness. After preparation, the apical and middle thirds of the root canal were filled with heated Gutta-percha resulting in an apical root filling of 5 mm (Fig. 1).

The 15-mm roots were randomly assigned to three groups (n = 10). In group MP, the roots were restored with cast metal posts (Goldent LA Copper–Aluminum Alloy; AJE Comercio Imp. Exp. Ltda., Sao Paulo, SP, Brazil) cemented with zinc phosphate (SS White, Rio de Janeiro, RJ, Brazil) (Fig. 2).

In group GP, a serrated glass fibre post (Reforpost; Angelus Science and Technology, Londrina, PR, Brazil) was cemented with a composite resin (Rely X ARC; 3M ESPE, St Paul, MN, USA) and a conventional two-step adhesive system (Adper Single Bond 2; 3M ESPE). Filtek Z 250 restorative composite resin (3M ESPE) was used for the core build-up.

In group AGP, together with the main post, three accessory glass fibre posts of different diameters (Reforpin; Angelus Science and Technology) were also cemented (Figs 3–5).

The 17-mm roots were randomly assigned to two other groups (n = 10). Roots of groups GP-R and AGP-R (Fig. 6) were restored in the same manner as GP and AGP; however, 2 mm of their remaining tooth structure was left intact (Table 1).

All samples were fixed in polyvinyl chloride rings with polystyrene resin at a level of 3 mm below the

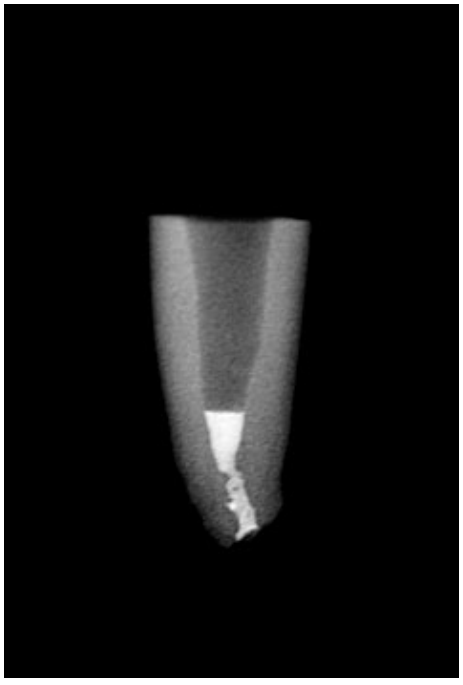

Figure 1 Radiographic image of root after intraradicular preparation and apical seal.

Figure 2 Sample with cemented cast metal core.

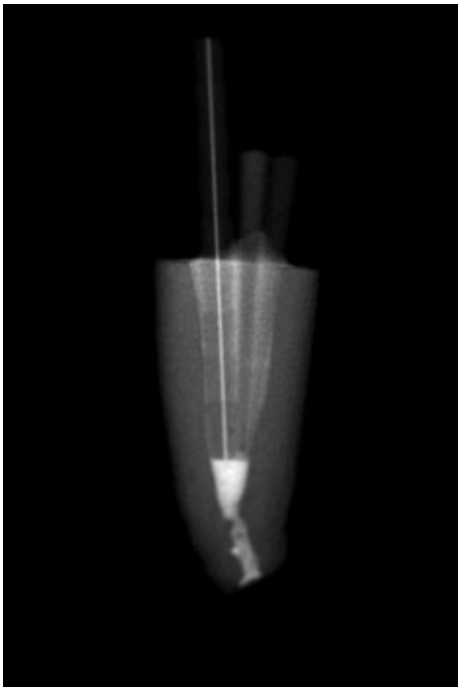

Figure 4 Radiographic image of posts position after cementation (group AGP).

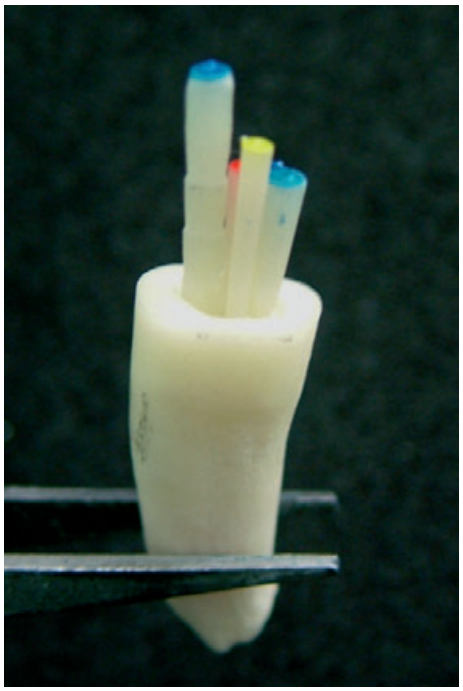

Figure 3 Main glass fibre post and three accessory posts before built-up (group AGP).

Figure 5 Samples of groups AGP.

Figure 6 Samples of groups AGP-R.

Figure 7 Fracture in coronal third (group AGP).

cervical margin of preparations simulating the biological width.

The fracture resistance test was performed with a compressive load at 0.5 mm min^{-1}. The samples were placed at the base of a universal testing machine (Kratos K 500 SMP, Cotia, SP, Brazil) at an angle of 135° in relation to the horizontal plane. The compressive load was applied 2 mm below the incisal edge on the palatal surface of the built-up core. All data were statistically analysed with one-way analysis of variance (ANOVA) at significance level of 5%.

Table 1 Experimental groups and restorative techniques

Group	Restorative technique
MP	Cast metal post and core cemented with zinc phosphate
GP	One main glass fibre post cemented with composite resin/core with composite resin
AGP	Four glass fibre posts (one main plus three accessory) cemented with composite resin/core with composite resin
GP-R	Same as GP, but roots with 2 mm of remaining coronal structure
AGP-R	Same as AGP, but roots with 2 mm of remaining coronal structure

After testing, all samples were removed from the rings with a diamond disk, the fracture modes (Figs 7 and 8) were classified as repairable or catastrophic (Heydecke *et al.* 2001) (Fig. 9), and were compared statistically using the Fischer's exact test.

Results

Table 2 shows the values of fracture resistance. There were no statistically significant differences amongst groups ($P = 0.65$).

The relationship between fracture resistance and fracture modes (Table 3) reveals only root fractures in group MP. In eight samples, they occurred in the cervical third of the root, whilst two occurred in the middle third of the root. In group AGP, no fractures occurred in the middle third of the root, nine occurred in the coronal portion and one in the cervical third). Groups GP-R and AGP-R did not present fractures in the middle third of the root but 50% and 60%, respectively, of fractures from these groups occurred in the cervical third. Fracture mode analysis by the Fisher's exact test revealed a statistically significant difference ($P < 0.05$) amongst groups MP, GP and AGP (Table 4).

Figure 8 Fracture in cervical third (group AGP-R).

Discussion

Thinning of root canal walls is an inevitable consequence of root canal treatment. Furthermore, the interruption of root development, extensive carious lesions and trauma may result in excessively wide canals and weakened roots. In such cases, a core may be required, not only to retain the future restoration (Libman & Nicholls 1995, Morgano 1996, Mannocci *et al.* 1999, Heydecke *et al.* 2001, Zhi-Yue & Yu-Xing 2003), but also to reinforce the remaining tooth structure (Lui 1987, 1994, Saupe *et al.* 1996, Kimmel 2000, Solomon & Osman 2003). It has been reported that the reinforcement of a wide root canal with composite resin, prior to the cementation of a cast metal post, could increase by 50% the fracture resistance of a root (Saupe *et al.* 1996). However, a combination of filling material and intraradicular post, capable of fully restoring the resistance of weakened roots, is yet to be described (Marchi *et al.* 2003).

According to previous studies (Newman *et al.* 2003, Fokkinga *et al.* 2004), cast metal and stainless steel posts provide high failure loads when compared with glass fibre posts. In the present experiment and in agreement with other studies (Barkhordar *et al.* 1989, Akkayan & Gülmez 2002, Zhi-Yue & Yu-Xing 2003), there was no statistically significant difference amongst groups (Tables 2 and 3) and all of them would theoretically withstand functional loads of 23 to 29 kgf in the anterior region of dentate patients (Ahlberg *et al.* 2003).

Regarding the fracture mode, an unfavourable dissipation of stresses (Toparli 2003) on teeth of group MP could explain the 100% of failures below the biological width in this group (Table 3).

When group MP is compared with GP, the risk of a catastrophic fracture is reduced for the latter. When glass fibre posts were used instead of cast metal, this result can be expected (Newman *et al.* 2003). Glass fibre posts have a modulus of elasticity similar to that of

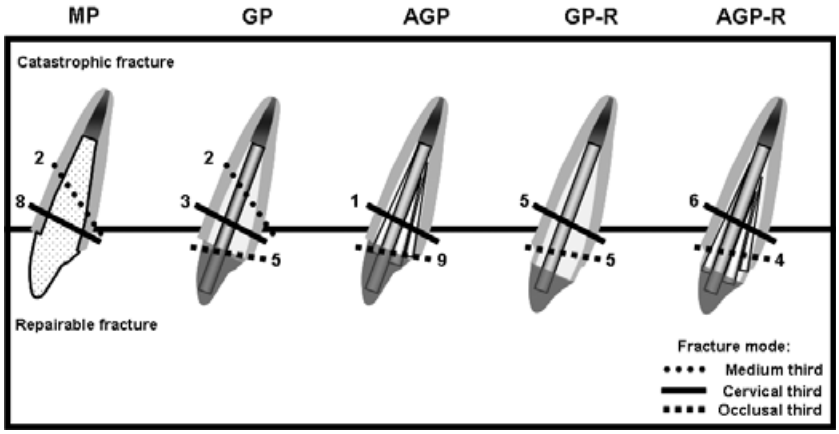

Figure 9 Locations and frequencies of fracture in five test groups. Fractures in coronal third were deemed repairable; fractures in cervical and medium third were deemed catastrophic.

Table 2 Resistance to fracture (kgf)

	Group				
N	MP	GP	AGP	GP-R	AGP-R
1	40.25	87.50	65.88	37.50	58.25
2	87.25	40.13	55.25	82.38	52.25
3	69.00	92.38	61.25	71.75	66.88
4	24.50	74.38	62.50	55.63	54.00
5	51.00	70.13	89.38	43.88	51.38
6	59.50	76.50	70.88	71.38	68.00
7	65.63	35.25	38.75	42.25	38.75
8	98.13	51.38	30.75	45.38	49.50
9	56.25	63.75	38.50	46.75	52.50
10	66.63	39.80	41.50	63.75	39.50
Mean	61.81	63.12	55.46	56.07	53.10
Sd	21.25	20.53	18.11	15.34	9.70
CV	34.40	32.52	32.65	27.35	18.26

SD, standard deviation; CV, coefficient of variation (%).

dentine, which would reduce the concentration and the intensity of functional loads on the root (Maccari *et al.* 2003). This beneficial mechanical condition is enhanced when comparing GP with AGP, where most of the space between root canal wall and the main fibre glass post is filled with accessory fibre glass posts in place of resin cement (Asmussen *et al.* 1999). In addition, a thinner layer of resin cement presents a reduced degree of polymerization shrinkage (Alster *et al.* 1997).

The fracture modes of group AGP (90% in the coronal third – Table 3) are in accordance with other studies (Akkayan & Gülmez 2002, Maccari *et al.* 2003, Newman *et al.* 2003). The mechanical behaviour of glass fibre posts probably increases the likelihood of repairable fractures, which are considered favourable because, in a clinical situation, they would have simplified the repreparation of the tooth (Mannocci *et al.* 1999), whilst vertical or catastrophic fractures would result in surgical crown lengthening or tooth extraction (Peroz *et al.* 2005).

Even considering that the proposed post space preparation is a pre-disposing factor for vertical fractures, it is of a secondary importance (Lassila *et al.* 2004) if a minimally sufficient dentine thickness of 1 mm around the entire circunference after post space preparation can be provided (Tjan & Whan 1985, Gluskin *et al.* 1995). Based on the root average diameter (6.9 mm) and the cervical diameter preparation (3.5 mm), and considering that external root morphology was reproduced during root preparation, it could be concluded that, in the present work, the remaining dentinal walls were not less than 1 mm in thickness.

Regarding the issue of remaining coronal tooth structure, the literature is controversial. Some studies report that a height of 2 mm (Saupe *et al.* 1996) or 3 mm (Melo *et al.* 2005) does not provide greater resistance to fracture of the test specimens, which was also observed in this study (Table 2). However, it has also been reported that as the intact coronal height increases, there is a proportional increase in the resistance to fracture (Isidor *et al.* 1999). In this study, perhaps the remaining structure in height was not sufficiently thick to provide a greater resistance because of the extensive internal preparation.

Another possible limitation of the present study may be the absence of a prosthetic restoration, which would certainly generate a different biomechanical effect. Based on the literature (Barkhordar *et al.* 1989, Erkut *et al.* 2004), the presence of a crown ferrule around the preparation provides greater resistance to fracture. On the other hand, it has been demonstrated that metal ceramic crowns on teeth with 2 mm of intact coronal structure did not increase the fracture resistance of root filled teeth (Zhi-Yue & Yu-Xing 2003).

Table 3 Resistance to fracture (kgf) for each fracture site (coronal, cervical or middle third of root)

	Fracture site							
	Coronal third of root		Cervical third of root		Middle third of root		Total	
Group	Mean	*n*	Mean	*n*	Mean	*n*	Mean	*n*
MP	–	0	59.33	8	71.75	2	61.81	10
GP	46.06	5	78.96	3	82.00	2	63.12	10
AGP	54.31	9	65.88	1	–	0	55.46	10
GP-R	45.53	5	63.09	5	–	0	56.07	10
AGP-R	49.55	4	56.65	6	–	0	53.10	10
Total	49.95	23	62.57	23	76.88	4	57.91	50

Table 4 Comparison amongst groups (Fischer's exact test)

Groups	Value of *P*	Significant
MP × GP × AGP	0.0002	Yes
GP × GP-R	0.3317	No
AGP × AGP-R	0.1409	No

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. No significant differences in fracture strength were detected amongst the five test groups.

2. Remaining sound tooth structure in the coronal third did not influence fracture resistance.

3. Glass fibre posts with composite cores associated with accessory posts led to a more favourable fracture mode in structurally compromised root filled bovine teeth.

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